TABLE OF CONTENTS ~ BEARINGS

5.7 Bearings

5.7.1 General

Bearings transmit forces from the bridge superstructure to abutments and piers. Therefore, the designer should consult the pretensioned prestressed concrete beam (PPCB) and continuous welded plate girder (CWPG) articles [BDM 5.4 and 5.5] and the abutment and pier articles in this manual [BDM 6.5 and 6.6] for additional information that may affect the design of bearings.

5.7.1.1 Policy overview [AASHTO-LRFD 14.6.2, 14.8.1]

The Office of Bridges and Structures follows a general design policy of jointless bridges with integral abutments for short and intermediate spans, within length and skew limits established on the basis of research at Iowa State University [BDM Table 6.5.1.1.1]. The jointless policy applies to all typical bridge superstructure types in use by the office—continuous concrete slab (CCS), pretensioned prestressed concrete beam (PPCB), continuous welded plate girder (CWPG), and rolled steel beam (RSB).

For many beam or girder bridges, integral connections between the superstructure and abutments are standard full-depth concrete diaphragms cast after the beams or girders have been seated on small steel S-shapes or bars [OBS SS 4500-4513, 4500-BTB – 4513-BTE]. In some cases for PPCB superstructures, the connections between the beams and piers are fixed, with full-depth concrete diaphragms cast after the beams have been seated on plain elastomeric pads. The full-depth diaphragms at abutments and piers require only the S-shapes, bars, or plain elastomeric pads during construction and, in usual conditions, these construction aids require no structural design.

Where bearings are required, the bearing designer needs to consider function, construction, inspection, maintenance, and replacement. Bearings shall be designed and detailed carefully to avoid maintenance problems. The designer should protect bearings from deck runoff. There should be room for inspection of bearings and space for jacking of the superstructure in case bearings need to be replaced [AASHTO-LRFD 14.8.1].

Where fixed bearings are required for PPCB, CWPG, and RSB bridges, the office prefers low profile, curved sole plate bearings of the type detailed on standard sheets [OBS SS 1010, 4541C-4541E]. Fixed bearings shall be designed to transfer longitudinal and transverse forces through anchor bolts, pintles, welds, steel plates, and other positive connections.

If the designer determines a need for expansion bearings, the office prefers steel reinforced elastomeric bearing pads as detailed on standard sheets [OBS SS 1010, 4541C-4541E]. The pads may be used with or without curved sole plates for pretensioned prestressed concrete beams, but for continuous welded plate girders curved sole plates are required. Although the expansion bearing details with curved sole plates theoretically can accommodate all transverse rotations, the elastomeric bearing pads should be designed for a minimum transverse rotation to allow for uncertainties. At each abutment or pier all steel reinforced elastomeric bearings shall have the same stiffness.

Bearing options for typical beam or girder bridges are summarized in Table 5.7.1.1-1.

Table 5.7.1.1-1. Bearing types for typical PPCB, CWPG, and RSB bridges

Support Type	Bridge Type	Bearing Description	Standard Sheets
Integral abutment (expansion/ fixed)	PPCB	S 3x7.5 (S 75x11) seat for A-D beams or 3x3 bar seat (75x75) for BTB-BTE beams, with full-depth concrete diaphragm	2078-2091, 4380-4385, 4380-BTB-4 – 4385-BTE-6, 4500-4513
	CWPG, RSB	S 3x7.5 (S 75x11) seat, with full-depth concrete diaphragm	RS40-21-<u>10</u>~~04~~ – RS40-24-<u>10</u>~~04~~
Fixed pier	PPCB	Plain elastomeric pad seat, with full-depth concrete diaphragm (1), (2)	4500-4513, 4542-4548, 4542-BTCDE – 4548-BTCDE
	PPCB	Low profile fixed bearing (1), (2)	4541C-4541E
	CWPG, RSB	Low profile fixed bearing (1)	1010, RS40-67-<u>10</u>~~04~~ – RS40-68-<u>10</u>~~04~~
Stub abutment (expansion)	PPCB	Steel reinforced elastomeric bearing pad or steel reinforced elastomeric bearing pad with curved sole plate and pintle plate (3)	
	CWPG	Steel reinforced elastomeric bearing pad with curved sole plate and pintle plate (3)	
Expansion pier	PPCB	Steel reinforced elastomeric bearing pad or steel reinforced elastomeric bearing pad with curved sole plate and pintle plate (3)	4541C-4541E
	CWPG, RSB	Steel reinforced elastomeric bearing pad with curved sole plate and pintle plate (3)	1010, RS40-67-<u>10</u>~~04~~ – RS40-68-<u>10</u>~~04~~

Table notes:

(1) Use fixed shoe bearings shown on OBS SS 1008b and 1009b only as needed to match existing bearings for bridge widening or rehabilitation projects or when needed for heavy loads or long-span structures.

(2) For PPCB bridges with slopes not more than 5.5% (0.055 radians) use the plain elastomeric pad seat, with a taper if necessary. See the plain elastomeric pad article [BDM 5.7.2.4.1]. For slopes greater than 5.5% (0.055 radians) the designer shall use a low profile fixed bearing [OBS SS 4541C-4541E].

(3) Use rocker or bronze plate sliding bearings shown on standard sheets [OBS SS 1008a, 1008b, and 1009a and 4541-4541B] only as needed to match existing bearings for bridge widening or rehabilitation projects or if load or expansion conditions exceed the permissible values for steel reinforced elastomeric bearing pads [BDM Table 5.7.1.1-2]. Check movement capacity of standard rocker or bronze plate bearings for the specific application.

For CCS bridges, connections between the slab and abutments are integral, without bearings, as detailed on the standard J-series plans. The connections between slab and pier caps are monolithic or nonmonolithic, without bearings.

To guide the designer in choosing the type of expansion bearing, the office has established the load and translation limits in Table 5.7.1.1-2.

Table 5.7.1.1-2. Service load and translation limits for expansion bearings

Bearing Type	**Maximum Service Load, kips (kN)**	**Maximum Service Translation (one direction), inches (mm)**	**Comments**
Steel reinforced elastomeric	450 (2000)	2½ (65)	Loads near the maximum are feasible at small translations. Large translations at small loads require anchorage of bearings.
Self-lubricating bronze plate (1), (3)	300~~156~~ (1334~~695~~)	1½ (38)	Larger loads and translations are feasible if bearings on standard sheets [OBS SS 4541-4541B]~~Standard Sheet 4541-4541B~~ are redesigned.
Rocker (2) (3)	650 (2891)	4½ (110)	Standard Sheets 1008a, 1008b, and 1009a also give smaller rockers with more limited capacities.
Disc or pot (4)	2500 (11,100)	5 (125)	Maximum limits are approximate and depend on manufacturer.

Table notes:

(1) The maximum load and translation are for the BTB-BTE bearing on ~~the right side of~~ the standard sheet [OBS SS ~~4541-~~4541B]. Other bearings shown on the standard sheets have lower maximum service loads.

(2) The maximum load and translation are for R5, the largest rocker on the standard sheets [OBS SS 1009a].

(3) Use rocker or bronze plate sliding bearings only as needed to match existing bearings for bridge widening or rehabilitation projects or if steel reinforced elastomeric bearing pads cannot be designed for the bridge load and expansion conditions.

(4) Of the two options, the office prefers disc bearings.

Bearings for bridges with unusual design requirements shall be selected on the basis of feasibility [AASHTO-LRFD 14.6.2] and economics, subject to approval of the supervising Section Leader.

In general the office requires that typical bearings and bearing parts be designed at the Service I limit state which, in a few cases, overrides requirements for strength limit state design in the AASHTO LRFD Specifications. Specially manufactured bearings such as pot or disc bearings may be designed according to the appropriate limit states in the AASHTO LRFD Specifications. Questions regarding design standards should be referred to the Chief Structural Engineer.

Except for bridge sites classified as Site Class F and Mississippi and Missouri River bridge sites the entire State of Iowa can be classified in AASHTO Seismic Zone 1 [BDM C6.6.2.10], and therefore the only usual design requirements for earthquake that affect bearings are minimum horizontal forces for connections and minimum bearing seat widths below deck expansion joints at discontinuities in the superstructure. For typical bridges with integral abutments, a continuous deck without expansion joints, and standard fixed pier and expansion pier bearings, connections and bearing seat widths need not be checked. However, bridges with any of the following features do need to be checked:

- Deck expansion joints,
- Horizontally curved beams or girders,
- Bronze plate bearings,
- Fixed shoe or rocker bearings,
- Pot, disk, or other high-load bearings,
- Stub abutments,
- Multiple simple spans, or

- Spans greater than 500 feet (152m).

5.7.1.2 Design information

Reserved

5.7.1.3 Definitions [AASHTO-LRFD 3.3.2]

Dead Load 1 is a designation for non-composite dead load that the office used with the AASHTO Standard Specifications. Under LRFD the office designates Dead Load 1 as DC1, non-composite dead load of structural components and nonstructural attachments [AASHTO-LRFD 3.3.2], which typically includes beams or girders, deck, haunches, diaphragms, and cross frames. It is applied to the beams or girders *before* the deck concrete cures.

Dead Load 2 is a designation for composite dead load that the office used with the AASHTO Standard Specifications. Under LRFD the office designates Dead Load 2 as either DC2 or DW based on the AASHTO definitions [AASHTO-LRFD 3.3.2]. DC2 is composite dead load of structural components and nonstructural attachments including barrier rails and sidewalks, curbs, and medians that are not part of the initial deck pour. It is applied to the composite beams or girders *after* the deck concrete cures. Curing of the concrete deck changes the load-carrying behavior of the superstructure by making the deck composite with the beams in PPCB bridges, with girders in CWPG bridges, and with beams in RSB bridges. Curing of the deck also imparts continuity over piers in PPCB bridges, except at expansion joints. Parts of DC2 are applied differently depending on design conditions. See the dead load information for PPCB and CWPG bridges [BDM 5.4.2.2.1, 5.5.2.2.1], design assumptions table for PPCB superstructures [BDM Table 5.4.2.4.1.1], and dead load information for bearings [BDM 5.7.2.1]. Under LRFD, future wearing surfaces and utility lines, which formerly were part of Dead Load 2, are in a new load designation, DW [AASHTO-LRFD 3.3.2].

Longitudinal is the direction associated with the axis of the girder or bridge member supported by the bearing. Usually the longitudinal direction will parallel the roadway centerline of construction. See Figure 5.7.1.3.

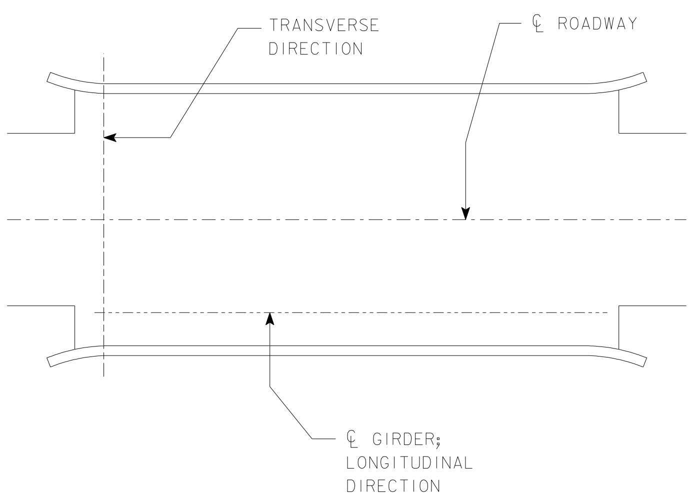

Figure 5.7.1.3. Longitudinal and transverse directions

Transverse is the direction normal to the axis of the girder or bridge member supported by the bearing. See Figure 5.7.1.3.

5.7.1.4 Abbreviations and notation [AASHTO-LRFD 3.3.2, C3.4.1, 3.10.4.2, 14.7.6.4, C14.8.3.1]

A_s, peak seismic ground acceleration coefficient modified by short-period site factor [AASHTO-LRFD 3.10.4.2]
CCS, continuous concrete slab
CWPG, continuous welded plate girder
DC1, non-composite dead load of structural components and nonstructural attachments such as beams, girders, deck, haunches, diaphragms, and cross frames [AASHTO-LRFD 3.3.2]. Before LRFD the office termed this load Dead Load 1.
DC2, composite dead load of structural components and nonstructural attachments such as barrier rails, sidewalks, curbs, and medians that are not part of the initial deck pour [AASHTO-LRFD 3.3.2]. Before LRFD the office considered these loads part of Dead Load 2.
DW, dead load of wearing surfaces and utilities [AASHTO-LRFD 3.3.2]. Before LRFD the office included these loads in Dead Load 2.
FR_E, friction force for a steel reinforced elastomeric bearing
LL, live load
LRFD, load and resistance factor design
PPCB, pretensioned prestressed concrete beam
RSB, rolled steel beam
S_{D1}, horizontal response spectral acceleration coefficient at 1.0-sec. period modified by long-period site factor [AASHTO-LRFD 3.10.4.2]
γ_{EQ}**,** load factor for live load applied simultaneously with seismic loads [AASHTO-LRFD C3.4.1]
μ, coefficient of friction for a steel reinforced elastomeric bearing on concrete, which may be taken as 0.2 [AASHTO-LRFD 14.7.6.4, C14.8.3.1]

5.7.1.5 References

American Concrete Institute (ACI). *Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05).* Farmington Hills: ACI, 2005. (Appendix D contains the latest information for design of anchor bolts in concrete. Research in process will fill in the gaps in the present appendix.)

American Institute of Steel Construction (AISC). *Steel Construction Manual, Thirteenth Edition.* Chicago: AISC, 2005.

Girton, D.D., T.R. Hawkinson, and L.F. Greimann. *Validation of Design Recommendations for Integral Abutment Piles, HR-292.* Ames: Iowa Department of Transportation and College of Engineering, Iowa State University, 1989.

Hartle, R.A., K.E. Wilson, W.A. Amrhein, S.D. Zang, J.W. Bouscher, and L.E. Volle. *LRFD Design Example for Steel Girder Bridge with Commentary.* Arlington: National Highway Institute, Federal Highway Administration, 2003.

Precast/Prestressed Concrete Institute (PCI). *PCI Design Handbook, Sixth Edition.* Chicago: PCI, 2004.

5.7.2 Load and displacement application

A bridge bearing transmits forces and displacements from superstructure to substructure with respect to three directions: vertical, longitudinal, and transverse as shown in Figure 5.7.2. Although most loads and displacements for bearings are determined from the superstructure using common structural principles, the office has some policies that simplify computations and produce conservative designs.

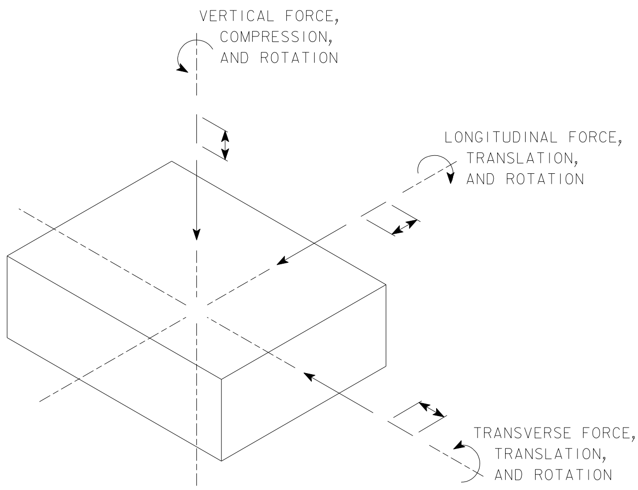

Figure 5.7.2. Bearing design loads and movements

5.7.2.1 Dead [AASHTO-LRFD 3.3.2, 4.6.2.2]

Dead load forces PPCB, CWPG, and RSB bridges shall be distributed to bearings according to AASHTO LRFD Specifications [AASHTO-LRFD 4.6.2.2] and the following office policy:

- Distribute DC1 forces assuming the deck to be simply supported between beams or girders and the deck overhang to be fully supported by the exterior beam or girder.
- For DC1 recognize continuity in CWPG [BDM 5.5.2.4.1.1] and RSB bridges.
- For bridges with roadways no more than 44 feet (13.200 m) wide, distribute the DC2 barrier rail load equally to all beams or girders. For bridges with roadways greater than 44 feet (13.200 m) wide, distribute each barrier rail one-half to the exterior beam or girder, one-quarter to the first interior beam or girder, and one-quarter to the second interior beam or girder.
- Distribute the DW, 0.020 ksf (960 Pa) future wearing surface equally to all beams or girders.
- Consider utility lines part of DW in accordance with the AASHTO LRFD Specifications [AASHTO-LRFD 3.3.2].
- Determine DC2 and DW forces considering continuity [BDM 5.4.2.4.1.1, 5.5.2.4.1.1]. Recognize the lack of continuity at expansion joints.

5.7.2.2 Live [AASHTO-LRFD 3.6.1.2, 3.6.1.3, 3.6.1.6, 4.6.2.2]

Unless special requirements govern the design, vehicular live load (LL) shall be HL-93 [AASHTO-LRFD 3.6.1.2]. It shall be applied as discussed in the AASHTO LRFD Specifications [AASHTO-LRFD 3.6.1.3]. If applicable, sidewalk loads [AASHTO-LRFD 3.6.1.6] shall be applied simultaneously with the vehicular live load.

Live load forces shall be distributed according to AASHTO LRFD Specifications [AASHTO-LRFD 4.6.2.2] and the following office policy:

- Determine live load (and dynamic load allowance, if applicable) forces considering continuity of PPCB bridges after curing of the deck.
- Distribute live loads as for beam or girder shear.

5.7.2.3 Dynamic load allowance [AASHTO-LRFD 3.6.2.1, Section 14]

Office practice is to exclude the dynamic load allowance (IM) from design of plain and steel reinforced elastomeric bearing pads but to include the dynamic load allowance in design of all steel bearing parts, even those parts transmitting loads from elastomeric bearings to substructure components. For special bearing types the designer shall consult the bearings section in the AASHTO LRFD Specifications to determine the applicability of the dynamic load allowance [AASHTO-LRFD Section 14].

Where applicable, the dynamic load allowance shall be determined according to the AASHTO LRFD Specifications [AASHTO-LRFD 3.6.2.1].

5.7.2.4 Thermal [AASHTO-LRFD 3.4.1, 3.12.2.1]

At expansion joints and expansion piers, where the superstructure is designed to move with respect to the substructure, the bridge designer shall determine the ranges and directions of translations caused by temperature change. For most superstructures the primary cause of translation is temperature change in superstructure members. As shown in Table 5.7.2.4 office policy is to design for one-half of the full range of cold climate temperature extremes increased by a setting factor for bearings that cannot be preset, in order to allow for a range of construction temperatures from 25 to 75°F (-4 to 24°C). The temperature policy differs from the AASHTO-LRFD Specifications as indicated in the table notes.

Table 5.7.2.4. Design temperature changes, setting factors, and thermal coefficient

Type of Superstructure	Design Temperature Change	Setting Factor Increase (3)	Thermal Coefficient
Steel	75°F each way from 50°F, 150°F temperature range (1) (42°C each way from 10°C, 84°C temperature range (1))	1.33 (1.33)	0.0000065 /°F (0.000012 /°C)
Concrete	50°each way from 50°F, 100°F temperature range (2) (28°C each way from 10°C, 56°C temperature range (2))	1.50 (1.50)	0.0000060 /°F (0.000011 /°C)

Table notes:

(1) The temperature range for steel superstructures generally is the same as for Procedure A cold climate in the AASHTO LRFD Specifications but offset upward 5°F (3°C) [AASHTO-LRFD 3.12.2.1].

(2) The temperature range for concrete superstructures is greater than the Procedure A range for cold climate in the AASHTO LRFD Specifications [AASHTO-LRFD 3.12.2.1]. The combination of temperature range and thermal coefficient closely approximates field measurements for an Iowa PPCB bridge determined by Iowa State University researchers under project HR-292 [BDM 5.7.1.5].

(3) The setting factor is intended to apply to elastomeric bearings and other bearings that cannot be adjusted for temperature at time of construction. The setting factor also substitutes for and exceeds the LRFD uniform temperature load factor [AASHTO-LRFD 3.4.1].

5.7.2.5 Shrinkage and creep

For bearing design the office neglects shrinkage and creep shortening of Iowa standard PPCB members because most of the shortening will have occurred before placing. In fast-track situations and in other prestressed concrete superstructure types the designer is cautioned to check shrinkage and creep as it affects dimensional changes of members.

5.7.2.6 Earthquake [AASHTO-LRFD C3.4.1, 3.10.3.1, 3.10.4.2, 3.10.6, 3.10.9.2, 4.7.4.1, 4.7.4.4]

Based on the acceleration coefficient S_{D1} [AASHTO-LRFD 3.10.4.2] for Site Class A though E [AASHTO-LRFD 3.10.3.1], all of Iowa shall be classified as Seismic Zone 1 [AASHTO-LRFD 3.10.6] for design of typical bridges [BDM C6.6.2.10]. For unusual cases where the bridge site is classified as Site Class F, and for Missouri River and Mississippi River bridge sites the designer shall determine the Seismic Zone based on the specific site characteristics.

Bridges in Seismic Zone 1 need not be analyzed for seismic forces (EQ) [AASHTO-LRFD 4.7.4.1]. However, connections that attach the superstructure to an abutment or pier so as to restrain relative movement shall be designed for horizontal connection forces. The acceleration coefficient A_S [AASHTO-LRFD 3.10.4.2] will vary below and above 0.05 in Iowa, generally below in northern Iowa and above in southern Iowa. Therefore the horizontal design connection force in restrained directions shall be taken as either 0.15 (if $A_s < 0.05$) or 0.25 (if $A_s \geq 0.05$) times the vertical reaction due to the tributary permanent load [AASHTO-LRFD 3.10.9.2]. The tributary load may vary from longitudinal to transverse directions as discussed in the AASHTO LRFD Specifications. The office neglects any live load in determining the connection force, consistent with $\gamma_{EQ} = 0.0$ [AASHTO-LRFD C3.4.1].

For an abutment or a pier at a deck expansion joint the designer shall provide the minimum bridge seat width for the expansion bearings [AASHTO-LRFD 4.7.4.4].

Many typical Iowa bridge designs meet the two seismic requirements because of standard details. The following bridge types need not be checked for seismic connection forces or bearing seat widths.

- CCS, standard J-series and custom designs with similar details.
- PPCB with all of the following: integral abutments, a deck without expansion joints, and standard pier bearing details [OBS SS 4541C-4541E].
- PPCB H-series and custom designs with similar details.
- CWPG with all of the following: integral abutments, a deck without expansion joints, and standard pier bearing details [OBS SS 1010].
- RS, standard series [OBS RS40-01-10~~04~~ – RS40-72-10~~04~~].

5.7.3 Load application to bearings [AASHTO-LRFD 14.4.1]

In each direction—vertical, longitudinal, and transverse—individual force and displacement components from the superstructure shall be combined to determine maximum and minimum design values for bearings. Maximum, minimum, and uplift vertical load combinations shall be considered in bearing design. The office recommends that the designer fill out a copy of the AASHTO LRFD bridge bearing schedule for each different type of bearing and include the schedules in the project computations [AASHTO-LRFD Figure C14.4.1-1].

5.7.3.1 Load modifier [AASHTO-LRFD 1.3.2, 3.4.1]

Load factors shall be adjusted by the load modifier, which accounts for ductility, redundancy, and operational importance [AASHTO-LRFD 1.3.2, 3.4.1]. For typical PPCB, CWPG, and RSB bridges with at least three parallel beams or girders the load modifier shall be taken as 1.0.

5.7.3.2 Limit states

Except for high load multirotational bearings and other bearings not specifically covered in this manual, the office requires that bearings be designed at the service limit state with an exception for the seismic connection force check as noted below. For steel reinforced elastomeric expansion bearings, all design in the AASHTO-LRFD Specifications is at the service limit state except anchorage. However, for consistency with previous practice the office requires that anchorage design also be at the service limit state. For steel bearing parts, designing for the service limit state with the limitations stated in a subsequent article [BDM 5.7.4.3] will be conservative with respect to strength limit states and essentially the same as design under the service load design method in the AASHTO Standard Specifications.

The seismic connection force check in the AASHTO LRFD Specifications required in Seismic Zone 1 makes use of more than one limit state. The horizontal force, which is considered an Extreme Event I force, is determined as 0.15 or 0.25 times the permanent dead load at the service level, without load factor adjustment. The office does not include live load when determining this horizontal force. The resistance of the connection then is checked at the strength limit state.

5.7.3.3 Load path

In each direction—vertical, longitudinal, and transverse—individual force and displacement components from the superstructure shall be combined to determine maximum and minimum design values for bearings. If the minimum vertical force is an uplift the designer shall consult with the supervising Section Leader regarding design options for the force.

Providing a complete load path from the superstructure to the substructure is particularly critical for longitudinal and transverse forces. The designer needs to check all elastomeric, steel, and concrete bearing parts from connection to the superstructure to connection to the substructure. Loads transmitted from superstructure to substructure components are covered in abutment and pier load application articles [BDM 6.5.2, 6.6.2]. For design checks not covered in this manual or the AASHTO LRFD Specifications, use design references such as *ACI 318-05* and the *PCI Design Handbook, Sixth Edition* [BDM 5.7.1.5].

For typical Iowa bridges, the most significant load and displacement design considerations are the following:

- Maximum and minimum combinations of forces along the vertical axis;
- Maximum combination of longitudinal forces;
- Maximum transverse wind force;
- Maximum and minimum combinations of rotation about the transverse axis due to profile grade, camber, dead load, live load, and uncertainties; and
- Maximum longitudinal thermal movement.

In cases where traffic turns to enter a bridge there will be transverse forces. At abutments with expansion joints and turning traffic, the designer shall estimate the transverse forces and provide lateral restraint at the bearings.

Expansion bearings need to accommodate longitudinal temperature and other translations with minimal longitudinal force. Although the primary translations usually are longitudinal, there also may be significant transverse translations in horizontally curved, skewed, or wide bridges.

For long-span bridges, curved bridges, highly skewed bridges, wide bridges, or other unusual bridges the designer needs to consider forces and movements carefully, both during the construction period and the service life of the bridge. During design, plan sketches of the bridge framing with longitudinal and transverse design values may be needed as a guide for proper design of the bearings.

5.7.4 Bearing component analysis, design, and detailing

5.7.4.1 Plain elastomeric pads

5.7.4.1.1 Analysis and design [AASHTO-LRFD 14.7.5.2, 14.7.6.3.2]

During construction of fixed piers with full-depth cast-in-place concrete diaphragms, office practice is to seat pretensioned prestressed concrete beams on 70 durometer plain, one-inch (25-mm) thick untapered or tapered elastomeric pads for slopes less than 5.5% (0.055 radians) [OBS SS 4500-4513, 4542-4548, 4542-BTCDE – 4548-BTCDE]. An untapered pad will accommodate slopes up to about 1.4% (0.014 radians). The slope is determined from the difference in bearing elevations without consideration of beam camber. Tapered pads for sloping pretensioned prestressed concrete beams shall have a centerline thickness of 1 inch (25 mm) and edge thicknesses specified to the nearest 1/16 inch (1.5 mm). At the maximum allowable 5.5% (0.055 radians) slope a 9-inch (230-mm) tapered pad will range in thickness from ¾ inch (19 mm) to 1 ¼ inch (32 mm).

The 70 durometer elastomer for plain elastomeric pads shall be virgin neoprene selected for temperature Zone C [AASHTO-LRFD 14.7.5.2] that meets Iowa DOT material and testing requirements [IDOT SS 4195.02].

Although plain elastomeric pads may not meet compressive stress limits for total vertical loads under the service limit state [AASHTO-LRFD 14.7.6.3.2], the pads have performed well in Iowa bridges under construction conditions detailed on office standard sheets [OBS SS 4500-4513, 4542-4548, 4542-BTCDE – 4548-BTCDE]. Under service conditions the pads are supplemented with preformed expansion joint filler below the concrete diaphragms, and thus the pads are unlikely to be subjected to full service load stress.

5.7.4.1.2 Detailing

See standard sheets for typical details [OBS SS 4500-4513, 4542-4548].

5.7.4.2 Steel reinforced elastomeric pads

5.7.4.2.1 Analysis and design [AASHTO-LRFD 14.4.1, 14.4.2.1, 14.7.5.2, 14.6.2, 14.7.6, C14.8.3.1]

Where expansion bearings are required for new bridges, the office prefers steel reinforced elastomeric bearing pads as detailed on standard sheets [OBS SS 1010, 4541C-4541E]. Steel reinforced elastomeric bearing pads shall be limited to service loads of 450 kips (2000 kN) or less and service shear deformations of +/- 2 1/2 inches (65 mm) or less, unless an exception is approved by the supervising Section Leader.

For long span bridges and other special conditions beyond the load and movement capacity of steel reinforced elastomeric bearings, the office recommends the following.

(1) Make preliminary selections of bearing types from AASHTO LRFD Specifications [AASHTO-LRFD 14.6.2], considering former Iowa standard fixed shoe, rocker, and bronze plate bearings as additional options.
(2) Check economic feasibility of the options.
(3) Seek approval of the supervising Section Leader before proceeding with final design.

The office recommends that the designer use the schedule given in the AASHTO LRFD Specifications [AASHTO-LRFD Figure C14.4.1-1] to summarize design values and requirements for each bearing design and include the summary sheets in the computations for the bridge.

At expansion bearings, rotations result from multiple sources including profile grade, camber, creep and shrinkage, construction tolerance, and loading. The applicable rotations for profile grade, camber, creep, and shrinkage should be determined directly from project information and the superstructure design process. To those rotations should be added the computed dead and live load rotations and the amount for uncertainties, 0.005 radians, given in the AASHTO LRFD Specifications [AASHTO-LRFD 14.4.2.1]. The dead and live load rotations will require analysis of bridge members under several service load cases with appropriate noncomposite and composite section properties.

In most cases a steel reinforced elastomeric bearing supporting a pretensioned prestressed concrete beam will not satisfy the AASHTO requirements for the sum of all design rotations. In those cases the designer should consider adding a curved sole plate, pintles, and a pintle plate with keeper bars above the bearing so that the bearing need only be designed for a minimal rotation [OBS SS 4541C-4541E]. With the curved sole plate, the bearing may be designed for the minimal rotation for uncertainties, 0.005 radians [AASHTO-LRFD 14.4.2.1], or less if approved by the supervising Section Leader. In all cases the curved sole plate, pintles, and pintle plate with keeper bars should be used with a steel reinforced elastomeric expansion bearing supporting a continuous welded plate girder [OBS SS 1010].

When a steel reinforced elastomeric bearing is loaded through a curved sole plate assembly, the bearing should be designed for a 0.005 radian rotation capacity under maximum downward service live and dead load. In cases when the bearing cannot meet the 0.005 radian rotation capacity or is subjected to a combination of dead load and upward live load that diminishes rotation capacity, the bearing may be used with approval of the supervising Section Leader.

For steel reinforced elastomeric bearing pads, the elastomer shall be virgin neoprene selected for temperature Zone C [AASHTO-LRFD 14.7.5.2] that also meets Iowa DOT material and testing requirements [IDOT SS 4195.02]. Nominal hardness should be specified as 50 durometer on the Shore A scale. In cases where 50 durometer elastomer does not meet design criteria, the designer may use 60 durometer elastomer. However, all elastomeric bearing pads for a single abutment or pier shall have the same hardness. The office prefers that the elastomer be formulated with minimal or no paraffin additives that may reduce friction on the surface of bearing pads.

For the specified nominal hardness, the shear modulus for each design condition shall be taken as the least favorable value from the AASHTO LRFD Specifications table [AASHTO-LRFD Table 14.7.6.2-1].

Internal laminates shall be ASTM A1011/A1011M, Grade 36 steel sheet. Preferred thickness is 0.125 inch (3 mm).

Steel reinforced elastomeric bearings shall be designed according to AASHTO Method A [AASHTO-LRFD 14.7.6].

Office policy is to design steel reinforced elastomeric bearings not to slip, and therefore elastomeric expansion bearings need to be anchored either by friction or positive restraints.

Expansion bearings can be anchored by friction in many typical conditions [OBS SS 1010, 4541C-4541E], such as where a steel reinforced elastomeric bearing is placed as follows:

- Between an ordinary rough concrete bearing seat and a concrete surface or hand wire-brushed galvanized steel plate bearing surface for a pretensioned prestressed concrete beam or

- Between an ordinary rough concrete bearing seat and a galvanized steel plate-keeper bar assembly below a pretensioned prestressed concrete beam or steel girder.

If there is insufficient slip resistance through friction, the bearing shall be restrained to prevent walking.

The friction force at the Service I limit state shall be computed as follows:

$$FR_E = \mu(DC1 + DC2 + DW + [-LL])$$

Where:

FR_E = friction force resistance for a steel reinforced elastomeric bearing, k (N)
μ = coefficient of friction, which may be taken as 0.2 [AASHTO-LRFD C14.8.3.1]
DC1 = non-composite dead load of structural components and nonstructural attachments [BDM 5.7.2.1.4]
DC2 = composite dead load of structural components and nonstructural attachments [BDM 5.7.2.1.4]
DW = dead load of wearing surfaces and utilities [BDM 5.7.1.4].
[-LL] = upward live load only; do not add downward live load. Usually upward live load is significant only at stub abutments for CWPG structures with an end span considerably shorter than the adjacent interior span. If the friction force is insufficient when upward live load is included, consult with the supervising Section Leader.

Steel reinforced elastomeric bearings placed between two steel or galvanized steel surfaces shall be restrained at each surface with keeper bars, vulcanization, or other means, unless the supervising

Section Leader approves an exception. Expansion bearings placed between steel surfaces usually are in locations where slip or walking of the bearings could cause severe structural problems, and therefore anchorage by friction is unacceptable.

5.7.4.2.2 Detailing

Steel reinforced elastomeric bearing pads shall have a minimum side cover of 1/8 inch (3 mm). Preferred layer thicknesses are ¼ inch (6 mm) for cover elastomeric layers, 1/8 inch (3 mm) for steel laminates, and 3/8 to ¾ inch (10 to 19 mm) for internal elastomeric layers as shown in Figure 5.7.4.2.2. Steel laminates shall be sheet material conforming to ASTM A1011/A1011M, Grade 36. Maximum thickness for bearings shall be 5 inches (125 mm), unless an exception is approved by the supervising Section Leader. Tapered elastomeric layers and holes are not permitted in steel reinforced elastomeric bearing pads.

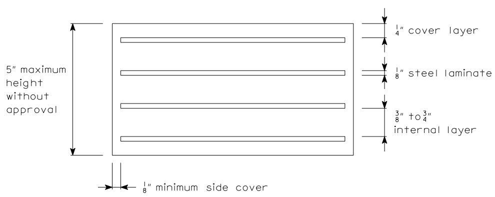

Figure 5.7.4.2.2. Steel reinforced elastomeric bearing design requirements

For restraint of a pad at a steel bearing surface see the office standard sheets for typical keeper bar details [OBS SS 1010, 4541C-4541E]. A pad also may be vulcanized to a steel plate as a means of attachment.

Dimensions between pads and abutment or pier edges are covered in subsequent articles in this manual [BDM 6.5.4.2, 6.6.4.1.1].

The designer shall provide space and stiffeners or specially designed diaphragms for CWPG superstructures for jacking and replacement of steel reinforced elastomeric bearings.

Where lateral restraint of expansion bearings is required the designer may use concrete shear blocks, steel angles bolted to bearing seats, anchor rods with slotted holes, or other acceptable details to provide transverse force capacity while maintaining longitudinal expansion capacity.

5.7.4.3 Steel bearing parts

5.7.4.3.1 Analysis and design [AASHTO-LRFD 14.4.1, 14.7.1.4]

Steel parts of bearings shall be designed at the Service I limit state, with one exception noted below, in accordance with the following office guidelines.

- For most bearing parts use Grade 36 steel [OBS SS 4541-4541B, 4541C-4541E], the default grade for structural steel in the standard specifications [IDOT SS 4152.02] or Grade 50 [OBS SS 1010]. If Grade 50 or a higher grade is required for bearing parts, the grade shall be specified on the plans. Plates directly attached to weathering steel girders should match the weathering steel grade of the girders. Single one-inch (25-mm) thick curved sole plates for pretensioned prestressed concrete beams shall be ASTM A 852/A 852M, A 514/A 514M Grade B, or A 709/A 709M Grade HPS-70W (HPS-485W) as noted on the standard sheet [OBS SS 4541-4541B, 4541C-4541H].
- Except as necessary for clearance, use plates in bearings at least 1½ inches (38 mm) thick and pintles at least 1½ inches (38 mm) diameter.
- For flexural design of plates use an allowable bending stress $F_b = 0.55F_y$. Include the dynamic load allowance when applicable in vertical load combinations (although dynamic load allowance

will be excluded for elastomeric bearing pads). Single one-inch (25-mm) thick curved sole plates for pretensioned prestressed concrete beams may be designed by LRFD at the Strength I limit state in order to maintain the one-inch (25 mm) thickness necessary for strand clearance.

- For shear design of plates use an allowable shear stress $F_v = 0.33F_y$. Include the dynamic load allowance when applicable in vertical load combinations.
- Deduct pintle holes for flexural and shear design of plates.
- Curved sole plates that bear on flat plates shall be designed for contact stress [AASHTO-LRFD 14.7.1.4]. Pintle holes need not be deducted from the line of contact stress.
- Design pintles for an allowable shear stress $F_v = 0.40F_y$ and an allowable bearing stress $0.80F_y$.
- Design masonry plates considering an allowable bending stress $F_b = 0.55F_y$, an allowable shear stress $F_v = 0.33F_y$, and an allowable concrete bearing stress $f_c = 0.30f'_c$. Masonry plate thickness should be equal to or greater than the diameter of the anchor bolts.
- When checking steel plates, pintles, welds, and anchor bolts for seismic connection forces, use factored strength limit state resistances.

The office recommends that the designer use the schedule given in the AASHTO LRFD Specifications [AASHTO-LRFD Figure C14.4.1-1] to summarize design values and requirements for each bearing design and include the summary sheets in the computations for the bridge.

5.7.4.3.2 Detailing

The designer shall provide a 1/8 inch (3 mm) thick neoprene leveling pad between each steel masonry plate and concrete bearing seat [BDM 11.10.2, E1010A/M1010A, E1010B/M1010B]. The neoprene pad shall be one inch (25 mm) larger in each dimension than the bearing surface of the steel plate and may be of 50, 60, or 70 durometer neoprene that meets requirements of the standard specifications [IDOT SS 4195.02]. The leveling pad need not be designed for compressive stress.

Dimensions between steel bearing parts and abutment or pier edges are covered in subsequent articles in this manual [BDM 6.5.4.2, 6.6.4.1.1].

When curved sole plates are required for pretensioned prestressed concrete beams, the designer shall include specific notes on the beam sheet in the set of bridge plans to show for which beams and at which ends the plates are required.

The curved lower surface of a sole plate and the upper surface of the plate on which the sole plate bears shall be finished to ANSI 250 (6.25 μm) before galvanizing [IDOT SS 2408.03, E, 6].

Steel bearing parts not made of weathering steel or stainless steel shall be protected after fabrication and welding with galvanizing [IDOT SS 4100.07] and/or an approved paint system [IDOT SS 2508, 4182] except where a coating would interfere with the function of the bearing.

Because of its high silicon and manganese content, weathering steel should not be galvanized.

5.7.4.4 Anchor bolts

5.7.4.4.1 Analysis and design

Anchor bolts (rods) are provided to secure bearings to abutments or piers and to carry horizontal forces between the superstructure and substructure. The bolts need to be designed for shear, bearing against steel plates, and anchorage to concrete. In cases where beams or girders are subject to uplift, anchor bolts also need to be designed for tension and combined shear and tension.

Typical low profile beam and girder bearings shall be secured with at least four 1½-inch (38-mm) diameter anchor bolts [OBS SS 1010], and fixed shoes and rockers shall be secured with anchor bolts as detailed on standard sheets [OBS SS 1008a-1009b].

Anchor bolts shall be checked at the strength limit state.

Office practice is to provide galvanized swedged anchor bolts in drilled holes as detailed on the standard sheets [OBS SS 1008b, 1009a, 1009b, and 1010], as described in the standard specifications [IDOT SS 2405.03, H, 2], and as specified in the instructional memo for inspection and acceptance of anchor bolts [OM IM 453.08].

The office will consider contractor requests to use anchor bolt wells in lieu of drilled-in or preset bolts. Requests approved in the past have involved bridges with:

- Beams or girders with wide bottom flanges that did not permit drilling at anchor bolt locations and
- High and varying skew combined with flared girders, which caused difficulty in avoiding the longitudinal reinforcing in the pier cap.

When the office does approve anchor bolt wells, it will require that one fixed pier has drilled-in or preset anchor bolts.

Anchor bolt wells typically are of two types:

- Stay-in-place, which usually are formed with corrugated metal ducts or
- Removable, which are formed with a greased PVC sleeve.

The office does not prefer the removable anchor bolt well because it requires extra care to thoroughly clean and roughen the void after removal of the greased sleeve.

A request for approval of anchor bolt wells shall include the following:

1. Stay-in-place-duct size and material specification, or removable well size and cleaning and roughening procedure.
2. Grout material specification.
3. Grouting procedure.
4. A diagram showing how the pier cap reinforcing will be shifted to accommodate the anchor bolt wells.

5.7.4.4.2 Detailing

Provide a minimum distance between center of an anchor bolt and edge of abutment or pier as required in subsequent articles in this manual [BDM 6.5.4.2, 6.6.4.1.1].

Anchor bolt locations shall be detailed with right angle dimensions from the center of the substructure unit as illustrated in Figure 5.7.4.4.2. Anchor bolt locations dimensioned in that manner will fit survey controls on the construction site and reduce chances for errors.

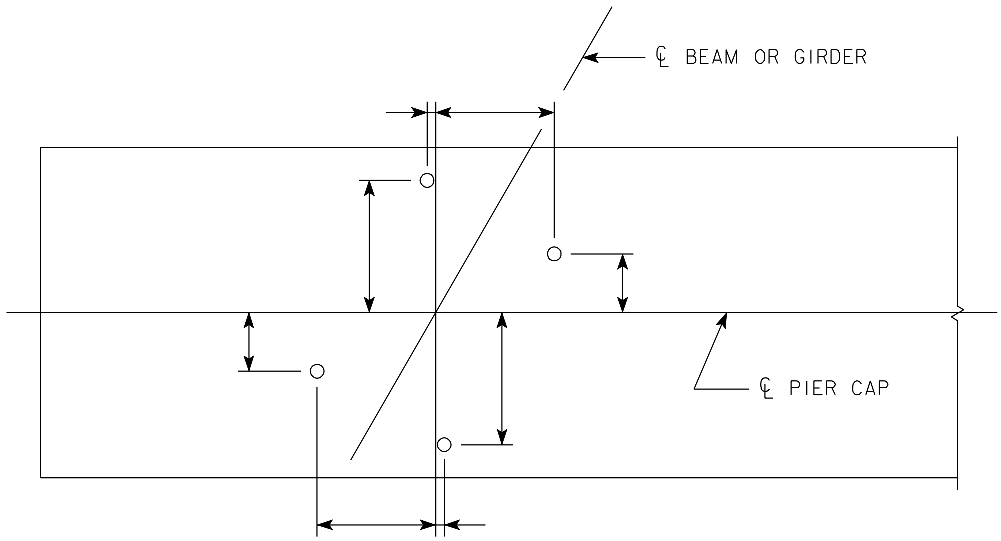

Figure 5.7.4.4.2. Anchor bolt dimensioning example

5.7.4.5 Fixed shoes, rockers, and sliding bronze plate bearings [AASHTO-I 1996 10.32.4.2, AASHTO-LRFD 14.7.1.4, 14.7.7.2]

5.7.4.5.1 Analysis and design

In general, design shall be at the LRFD Service I limit state. However, in cases where bearings are intended to match those in an existing bridge, the supervising Section Leader may approve design by the AASHTO Standard Specifications.

For widening of existing bridges the designer shall seek to use bearings that closely match those in the existing bridge. Consult standard sheets for fixed shoe, rocker, and sliding bronze plate bearings of the type specified by the office in the past. Also consider fixed shoe and rocker bearings for bridges with relatively long spans or heavy bearing loads. Other use of fixed shoes, rockers, and sliding bronze plate bearings must be approved by the supervising Section Leader.

Fixed shoes and rockers on the standard sheets were designed with bearing formulas in the AASHTO Standard Specifications [AASHTO-I 1996 10.32.4.2] that were altered with the 1997 interim. Those bearings [OBS SS 1008a-1009b] will not meet the present more conservative contact stresses [AASHTO-LRFD 14.7.1.4]. For the unusual situation when it is necessary to design bearings similar to the standard fixed shoes and rockers, the designer should use the AASHTO bearing formulas from 1996 and earlier.

Special sliding bronze plate bearings that have load or movement capacities beyond those on the standard sheets [OBS SS 4541-4541B] may be designed with the following compression and coefficient of friction limits.

- Maximum nominal bearing stress at the service limit state of 2.0 ksi (13.8 MPa)
- Minimum coefficient of friction of 0.1 [AASHTO-LRFD 14.7.7.2]

5.7.4.5.2 Detailing

Anchor bolt locations shall be detailed with right angle dimensions from the center of the substructure unit as illustrated in the anchor bolt detailing article [BDM Figure 5.7.4.4.2]. Anchor bolt locations dimensioned in that manner will fit survey controls on the construction site and reduce chances for errors.

5.7.4.6 Disk and pot bearings

5.7.4.6.1 Analysis and design

Reserved

5.7.4.6.2 Detailing

Disk and pot bearings are selected by the contractor after contract letting, and heights for appropriate bearings will vary. The designer shall make allowances for typical bearing heights when designing abutments and piers but shall not give final bearing seat elevations. Dimensions and notes on the plans shall indicate the need for the contractor to determine bearing seat elevations, as indicated in Figure 5.7.4.6.2.

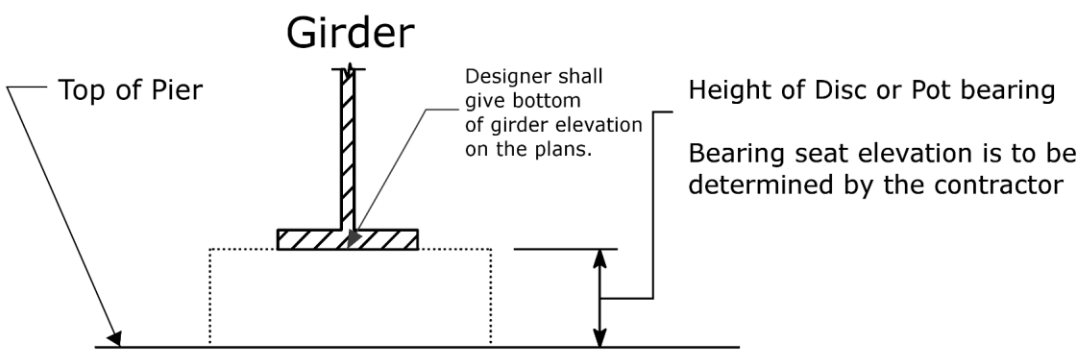

Figure 5.7.4.6.2. Disk or pot bearing elevations